Vol 5 Issue 6 July 2015

ISSN No : 2230-7850

International Multidisciplinary Research Journal

Indian Streams Research Journal

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RNI MAHMUL/2011/38595 **ISSN No.2230-7850**

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Indian Streams Research Journal
ISSN 2230-7850

Impact Factor : 3.1560(UIF)
Volume - 5 | Issue - 6 | July - 2015

INTEGRATING CHANNEL CUT-OFF AND CULTURAL LANDSCAPE: A CASE STUDY OF CHAKUNDI VILLAGE AMIDST THE CHAR-CHAKUNDI CUT-OFF OF RIVER BHAGIRATHI, WEST BENGAL

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ABSTRACT

channel cut-off is a natural geomorphic phenomenon in the hydro-dynamics of a fluvial system. Cut-off not only affects the hydraulics of the river but the socio-economic landscape of a region. In the present paper sequential development of the Char-Chakundi cut-off of River Bhagirathi and its impact on cultural landscape of Chakundi Village of Nadia District, West Bengal has been portrayed. Landscape morphology of the Village has gone drastic changes after this cut-off. Formation of Char-Chakundi Cut off has made the Chakundi village an 'Isolated State'surrounded by paleo-channel of River Bhagirathi. A village level perception survey establishes that out of eight socio-economic variables four variables viz. agriculture, fish catch, issue of social security and building quality have shown positive rating while the remaining four variables viz. recreation, transportation system, access to health and access to education facilities have shown negative rating in the post cut-off stage. This applied work is constituted by the integration of remote data and field data. This paper aims to improve integration between geomorphology and 'landscape morphology'.

KEYWORDS :*Applied Geomorphology, landscape morphology, Isolated State, Char-Chakundi Cutoff, Chakundi Village,River Bhagirathi.*

INTRODUCTION

A meander in general is a bend in a sinuous watercourse which is formed when the moving water in a stream erodes the outer banks and widens its valley. A stream of any volume may assume a meandering course, alternately eroding sediments from the outside of a bend and depositing them on the inside. The result is a snaking pattern as the stream meanders back and forth across its down-valley axis. Meandering rivers, exhibiting progressive change in channel location as they migrate across their floodplains over time, is not only complex but has a role in floodplain development and landscape evolution and also has economic and social consequences of bank erosion and channel migration. Therefore, improved understanding of the dynamics of river meandering plan forms is of practical as well as of scientific interest (Güneralp and Rhoads, 2009). Meander cutoff is an important phenomena related with meandering. A meander cutoff occurs when a meander bend in a river is breached by a chute channel that connects the two closest parts of the bend (Strahler and Strahler, 1996). This causes the flow to abandon the meander and to continue straight down slope. Cutoffs are a natural part of the evolution of a meandering river,

Short Profile

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and have also been used to artificially shorten the length of meandering rivers for navigation. The stagnant part of the river will sometimes form an oxbow lake.Meanders can develop more complex forms, for examplebends with two apices (double heading) or where lobes form on existing bends (Hooke and Harvey, 1983).However, meander bends do not continue to grow indefinitely, or the channel slope would become too gentle to allow transport of the sediment load. Instead, a negative feedback mechanism comes into operation, when individual meander loops become 'short-circuited' to form a cutoff. This process shortens the channel length, with a resultant increase in the channel slope. Two main types of cutoff are observed: neck cutoffs and chute cutoffs. Neck cut-offs are the most common(Strahler and Strahler, 1996)and (Knighton, 1998). In this present study area neck cut-off has been observed.Shifting of river course, meandering and meandering cutoff all are very common in nature. But these common natural events have great impact on human economy, society and culture(Islam, 2013 ; Islam and Guchhait, 2014). These natural events sometimes provides a lots of economic opportunities and potentialities by means of providing fertile lands, fishing, aquaculture, irrigation etc. and sometimes it snatches out human set-ups by means of flood, bank erosion, shift in river course, meander cutoff etc. that ultimately forces human to migrate geographically and occupationally, shifting of settlement and resettlement etc. So the dynamism of river is also connected with the life and livelihoods of people of the char lands(Lahiri-Dutt and Samanta, 2013).

Threfore in this present paper the follwing objectives have put forth:

i)to trace out the sequential stages of development of Char-Chakundi Cut Off

ii)Impact of cut off on socio-economic conditions of Chakundi Village along the River Bhagirathi of Nadia district

iii)Integrate geomorphology and landscape morphology

2. STUDY AREA

The area that has been selected to develop the research work is located inthe western bank of the River Bhagirathi in Kaliganj block of Nadia District (Fig. 1). It measures around 344 hectare area. Latitudinal and longitudinal extension of the area are 23^0 36' 56'' N to $23^0$38' 46'' N and 880 13' 44'' E to 88^0 14' 59'' E.The landscapehas been shaped by fluvial processes and is a patchwork ofpaleo channel cross-cut by active channels. In terms of physiography, Chakundi Village is a part of Gangetic deltaic plain. It generally slopes towards the paleo channel River Bhagirathi. Its highest altitude is 20 Meter, located insoutheastern part; lowest altitude is 10 Meter and the relative relief is 10 meter.The area is drained by the north-south flowing River Bhagirathi encroaching the Mouzawith time. This area contains a distinct palaeo-channel of the Bhagirathi River and the marshy land along with some ponds which is locally known as Chhari Ganga. The area is characterized by hot, humid monsoon climate. Meteorological stationKrishnanagar, the nearest station to Chakundi, records mean of the dailymaximum temperature 330C and mean of the daily minimum temperature 20.10C andaverage annual rainfall 137.28 cm (India Meteorological Department, 1999).The soil profile exhibits clear two zones:upper one is basically silty layer and the lower one is sandy(Parua, 1992).

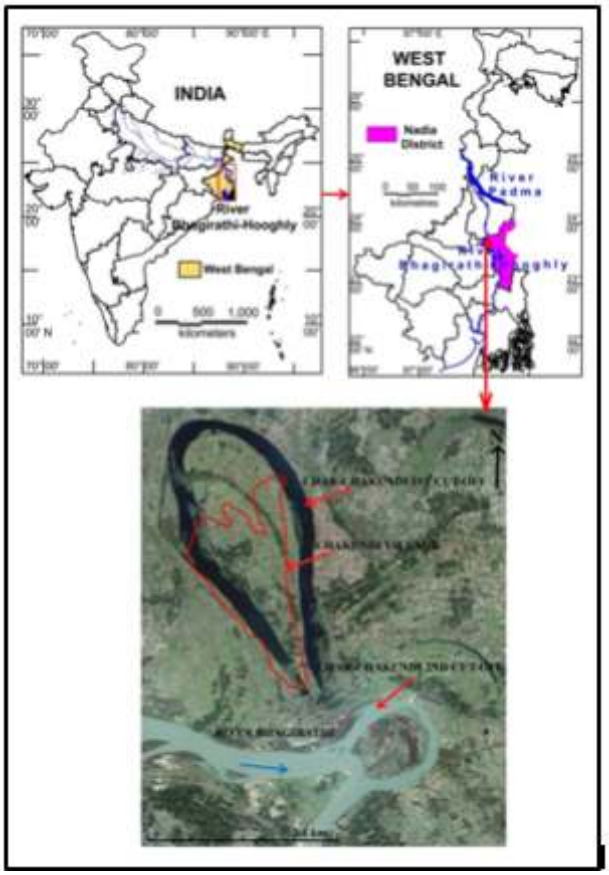

Figure: 1 Location of the Study Area

3. Data Base and Methodology

Primary Data

Primary information has been collected through intensive field survey. Field investigation has been conducted taking 10% sample on a random basis. As per 2011 Census, there were 287 households, out of which 29 households were selected for the present analysis. The primary data regarding socio-economic set-up have been collected as only ordinal data i.e. whether impact was positive or negative. Respondents are asked to indicate their level of agreement with a given statement by way of an ordinal scale (Lickert, 1932).Then further improvement in the collection of quantitative data was performed using 5-point Lickert Scale to magnify the severity of impact by cut-off development on the livelihoods of the villagers.

Secondary Data

a. District Census Hand Book, Nadia from1991 to2011.

b.Satellite Images

Sl. No.	Date of Acquisition	Projection	Datum	Resolution (Meter)	Source
1.	29.03.1975	UTM	WGS 84	60	Landsat 2, MSS
2.	2001	UTM	WGS 84	30	Landsat 5, TM
3.	18.03.2007	UTM	WGS 84	30	Landsat 5, TM
4.	06.04.2014	UTM	WGS 84	30	Landsat 8, OLI/TIRS

Source: U.S. Department of the Interior , U.S. Geological Survey, 2015

For carrying out the research work a systematic methodology has been followed. After the selection of the problem and study area, an extensive literature has been surveyed. Then a questionnaire was framed after the initial pilot survey in the village. Thus a sound data base from various sources and field work has been prepared. The data have been treated spatially and statistically with help of software.

The layers of Satellite Images have been fed into Erdas 9.2 Software and stacked into one image in standard FCC form. After that image rectification has been done by histogram equalization technique. From that rectified image nature of evolution of Char-Chakundi Cut-off has been portrayed with time.

The socio-economic data have been treated by uni-variate and multi-variate techniques. Responses from the villagers have

been portrayed through the ratio, mean and co-efficient of variation.

Ratio has been calculated as:

$R = \frac{x}{n}X100$ (where, R is the Ratio; x, individual value, n, total value

$Mean\ (x') = \frac{\sum x}{n}$ here x, individual value; n, total frequency

$Mean = \frac{SD}{\bar{x}'}$ X100 (where, SD, Standard Deviation)

For multivariate analysis Principal component analysis (PCA) has been embraced.

PCA is a widely used data reduction technique. The PCA is computed by determining the eigenvectors and eigenvalues of the covariance matrix. The covariance of two random variables is their tendency to vary together. This expressed as:

$cov(X, Y) = E[E[X] - X] \bullet E[E[Y] - Y]$ ----------(1) (Greg, 2006)

Where E[X] denotes the expected value of X

For sampled data this can be explicitly written out as:

$Cov\ (X,Y) = \sum \frac{\Sigma(x-x')(y-y')}{n}$ ---------- (2) (Greg, 2006)

$\bar{x}$ = mean(X) and $\bar{y}$ = mean(Y). Note that cov(X, X) = var(X), and for independent variables cov(X, Y) = 0. The covariance matrix is a matrix A with elements Ai,j = cov(i, j). The covariance matrix is square and symmetric. For independent variables, the covariance matrix will be a diagonal matrix with the variances along the diagonal.

To calculate the covariance matrix from a dataset, first center the data by subtracting the mean of each sample vector. Considering the columns of the data matrix A as the sample vectors, we can write the elements of the covariance matrix C as:

$cij = \frac{1}{n}\sum_{i=0}^{n} aijaji$ ---------- (3) (Greg, 2006)

Written in Matrix form:

$C = \frac{1}{n}$ AAT---------- (4) (Greg, 2006)

Often the scale factor 1/N is distributed throughout the matrix and the covariance matrix is written simply as AAT.

For the present analysis PCA has been performed with the help of SPSS software using systematic methodology (Fig. 2).

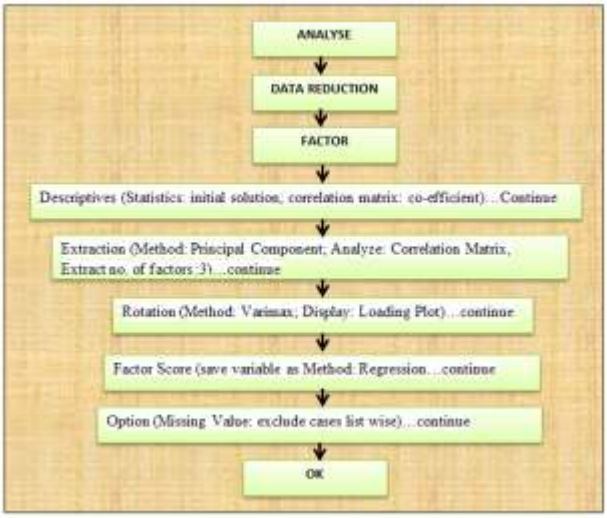

Fig. 2 Flow Chart of Work Procedure for PCA in SPSS Software

4. RESULTS AND DISCUSSION

4.1 Evolution of Char-Chakundi Cut-off

The cutoff landmass of the river Bhagirathi of Nadia is locally known as char. The present study is aimed at Char-Chakundi cut-off of River Bhagirathi. The Nadia segment of River Bhagirathi is very unstable and dynamic in nature.The instability and dynamisms are due to the shift of the main channel flow of Ganga towardsEast due to the eastward tilting of tilt of the Bengal basin. (Allison, 1997; Allison and Kepple, 2001; Goodbred, 1999, 2003; Subramanian and Ramanathan, 1996; Kuhel, 2005; Kuhel et al. 1989) The instability of the Study Area in the Lower Reach of the River Bhagirathi is also contributed by the Fluctuating River Regime of Ajay. As a result,lower reach of Bhagirathi became instable and that culminates in river meandering,meandering cut-off,bank erosion and formation of ox-bow lakes. Char-Chakundi cutoff is a replica of the whole phenomena. The whole event of Char-Chakundi cutoff could be conveniently classified into four successive stages, which have been stated below.

Phase – I: Pre Cut-off Stage of Char Chakundi 1st Cut-off

In the first phase, that is prior to 1970 a

large open meander start growing near Kalikapur. The Gradualism coupled with episodic erosion near this region converted this open meander into a close and acute one with high amplitude (3.59 km), higher arc angle(2070), and lower neck width (650m) and higher amplitude -neck width ratio (5.52) (Fig. 3.a)

Phase –II: Post Cut-off Stage of Char Chakundi 1st Cut-off

Within 25 years of geomorphic evolution of the cut-off near Kalikapur, Char –Chakundi 1st Cut off emerged in in 1994 as a response to neck cut-off. This cut off reduced river length by 11 km. From the satellite image of 2001, it has been observed that the large bend of the river has cut off from main stream, and the rejected channel forms an oxbow lake (Fig. 3.b).

Phase – III: Pre Cut-off Stage of Char Chakundi 2nd Cut-off

Phase III experienced the gradual evolution of the channel near Kalikapur and another mender emerges to grow in dimension and acuteness. But this meander is of small size compared to the first one. Amplitude(1.66km), neck width (523m) and amplitude-neck width ratio (3.17)are less that of the first one. (Fig.3.c)

Phase – IV: Post Cut-off Stage of Char Chakundi 2nd Cut-off

This stage saw the formation of a new cutoff i.e. Char Chakundi 2nd cut-off in 2008. It only reduced 3.6 km of the length of the river. This cut off is suddenly formed taking less than 14 years. This cut-off is formed due to chute cut-off (Fig. 3.d). This cut off has given birth to another ox bow lake, though this lake an active connection with main channel especially in the freshet.

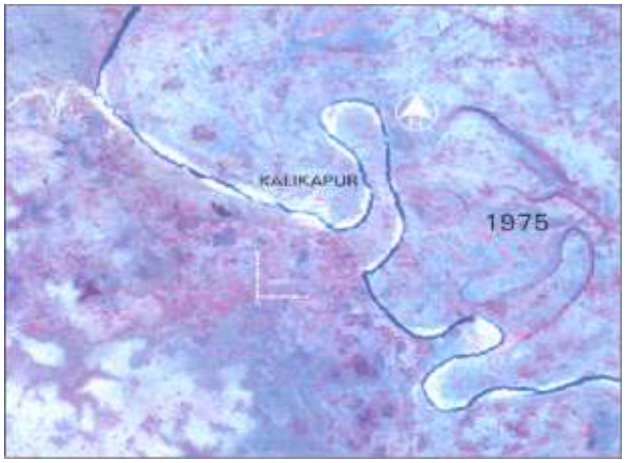

Fig. 3.a.Acute Meander Growth and Pre Cut-off condition for Char-Chakundi Cut-off I in 1975

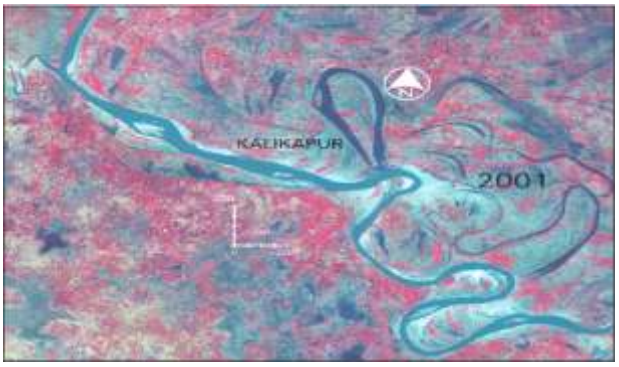

Fig. 3.b. Post Cut-off condition for Char-Chakundi Cut-off I in 2001

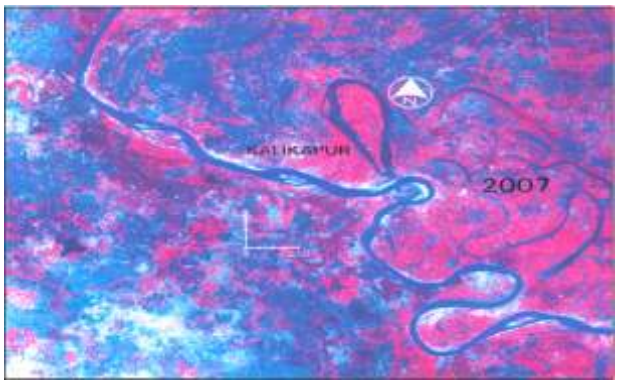

Fig. 3.c. Gradual Meander Growth and Pre Cut-off condition for Char-Chakundi Cut-off II in 2007

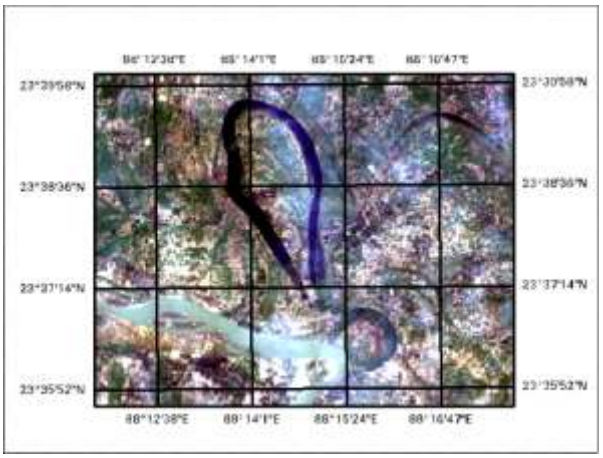

Fig. 3.d. Post Cut-off condition for Char-Chakundi Cut-off II in 2014

4.2 Impact of Channel Cut-off on Cultural Landscape

River cutoff is not only a mere geomorphic phenomenon but it also has a great impact on society. In the present study it has been analyzed the impact of river cutoff on civil life and economy of the people.

Impact on Natural Hazards

The whole event of channel cutoff has affected the nature and intensity of natural hazards in the Chakundi Village. The area was mainly affected by two types of geomorphic hazards i.e. flood and bank erosion. But, after the channel cutoff the intensity, frequencies, nature of the hazards have changed. In the pre cutoff stage the area was mainly affected by annual flood and pronounced amount of bank erosion. But after the cutoff the intensity of both flood and bank erosion has decreased considerably in a sound manner, as per the people the intensity of bank erosion has decreased up to 4.65 in rating scale and the intensity of flood has decreased up to 2.85 in rating scale (Fig.4) That indicates the lowering of the frequencies and effects of both of the hazards.

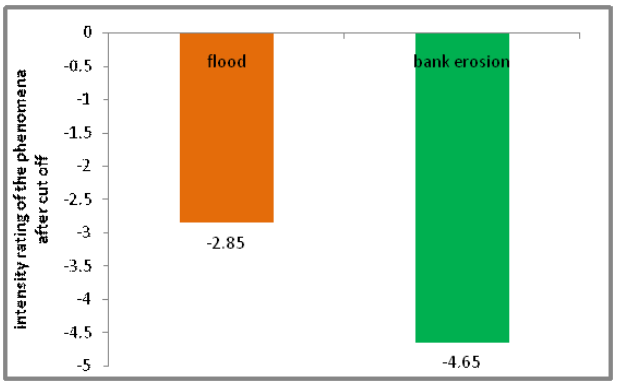

Fig: 4 Intensity of Flood and Bank erosion after Cutoff(Field Work, 2015, sample size: 29)

Impact on Cultivation

Cultivation is the main occupation of the people of Chakundi Village. Channel cutoff has major impact on cultivation, as it affects the farming in a two way process.Occurring of annual floods and profuse bank erosion were very common phenomena before the cutoff. Both of the events had a negative effect on cultivation. But after the channel cutoff the intensity of flood and bank erosion has decreased categorically, which hasenabled stability in cultivation and consistency in production. So a major portion of the respondents have positive perception about the channel cutoff (Fig.5.a,b). On the other hand, some people also have the view that, channel cutoff has decreased the chance and degree of accumulation of new alluvium by lowering the frequency of flooding. That ultimately decreased soil fertility.

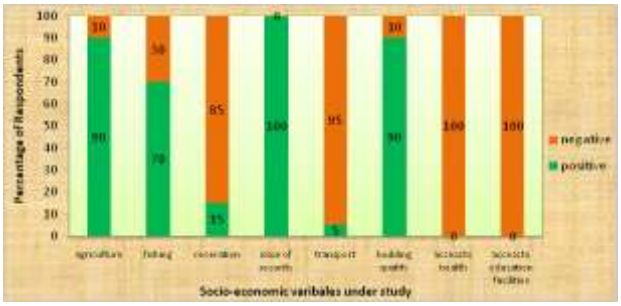

Figure: 5.a. Negative and positive responses of the respondents on various indicators(Field Survey 2015, sample size: 29)

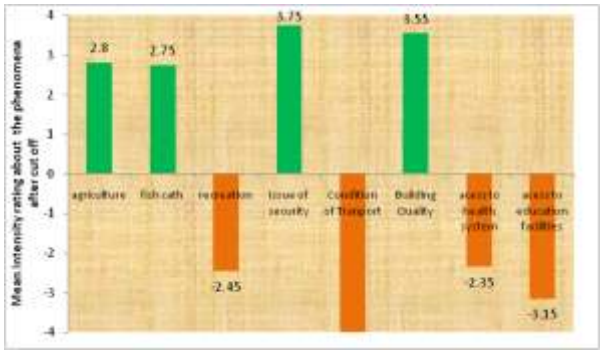

Figure: 5.b. Mean Intensity Rating of different Socio-economic variables (Field Survey 2015, sample size:

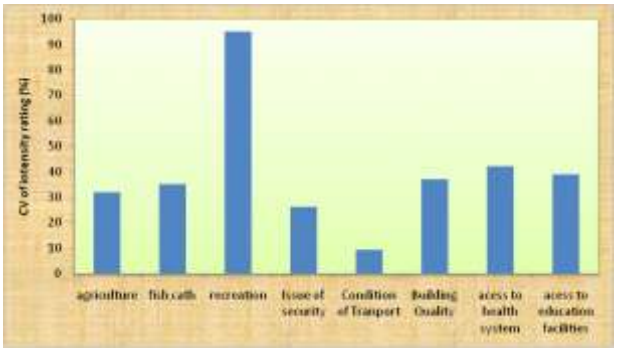

Figure: 5.c. Coefficient of Variation (CV) of Intensity Rating of different Socio-economic variables (Field Survey 2015, sample size: 29)

Fishing activity

Fishing activity was a subsidiary economic activity before the channel cutoff. It was very tedious job for fishing in an open and active river like River Bhagirathi, as it needed modern fishing equipment, large boats etc. That was quite unaffordable to the fishermen on that period. After the channel cutoff, theformation of oxbow lake has opened a huge potentialityin fishing, because now it does not need large boats and other equipment (Fig. 6). So, the intensity and importance of fishing has grown up after the channel cutoff. Most of the respondents (70%) have the belief that, fishing condition has developed in post cutoff era (Fig.5.a,b).

Fig.6. a, b: Fishing in oxbow lake at Char-Chakundi; c: Bathing in River, a mode of recreation; d: Transport and communication(Field Survey, 2015)

RECREATION

Channel cutoff has also influenced the recreational environment of the people of the char land. As per the view of the people they were more satisfied in bathing, using and to passing their time with the River Bhagirathi as an active and lively river. As majority of the villagers belongs to the Hindu community so, they have a soft religious corner for the River Bhagirathi (Fig.6). But now being detached from main channel flow most of the villagers (85%) are not satisfied aesthetically (Fig.5.a,b). Rating in this variable is most fluctuating as it records >90% coefficient of variation (CV) in perception of the people. So this variable is less reliable (Fig. 5c). So it basically controlled by the perception of the people.

SOCIAL SECURITY

The question of social security has changed pronouncedly after channel cutoff. It has been found that before the cutoff, when the area were connected with the main land by a chicken neck land mass or corridor then it was very easy for the anti-socials and the robbers to indulge their unfair activities and to flee through the corridor.Nowadays socialsecurityof Chakundi Village is in a very suitable and stable condition (Fig.5.a, b).After the detachment from the main

channel and the completion of oxbow lake formation, the whole area has been encircled by a trench like palaeo channel of Bhagirathi, which have made the area inaccessible for the invaders. The perception of the people about the social security varies least .i.e. this is the most reliable variable (Fig. 5.c).

TRANSPORT

The transport system of the area has been adversely affected by channel cutoff. In the pre cutoff stage the area were closely linked with the main land through a corridor, then the area were well accessible. But in the post cutoff period the area has been turned into an island, encircled by an oxbow lake, which has negatively affected the socio-economic fabric of the ChakundiVillage. According to the respondents in the post cutoff period the transport system has been disrupted completely (Fig.5). The CV of respondents' rating show minimum value signifying the consistency of the phenomena.

BUILDING QUALITY

Unlike the transport system the building quality of Chakundi village has developed well in the post- channel cutoff period. Before cutoff stage hazards like flood and bank erosion were very common and intensified in nature. Destruction and damaging of the houses were a very natural event then. As the area were vulnerable to flood and bank erosion, so the people naturally used to build temporary constructions like; bamboo fenced and hay roofed houses. In the post-cutoff period, as the intensity of flood and bank erosion has decreased, so the people are now are interested to build permanent constructions or pucca houses (Fig.5). Finally it could be concluded that the building condition in Chakundi village has developed in the post-cutoff period.

HEALTH SYSTEM

In the Chakundi village health condition of the people and health services are poor. The Village does not possess any kind health service centers. People have to avail health services from the Kaliganj Block health centre. Though there is no direct relation between the health scenario of a village and channel cutoff, but indirectly it has some impact. Presently the kind of health service is available in Chakundivillage is similar to the services available at pre channel cutoff period. But in present the channel cutoff have provided a natural barrier to the transport and communication system, which has decreased the ability of people to access the common health services. That ultimately has worsened the overall health scenario of the Chakundi Village (Fig.5).

EDUCATIONAL FACILITY

Likewise the health function, channel cutoff has also affected the educational scenario of the Chakundi village. The village contains only a single primary school. After the completion of primary education the students have to go to the high schools far away from the village for further education. But after the channel cutoff it has been really a tough work for the students to go out of the village by crossing the oxbow lake all the time. That ultimately has put a barrier upon the accessibility to education (Fig.5).

MULTIVARIATE TREATMENT OF THE SOCIO-ECONOMIC VARIABLES

Eight Socio-economic variables have been selected for Multivariate analysis. The variables are Agriculture (A), Fish Catch (F), Recreation ®, Issue of Social Security (S), Transportation and Communication (T), Building Quality (B), Access to Health Services (H), and Access to Educational Facilities (E). Taking these variables in SPSS principal Component analysis has been performed. From the Correlation matrix it has been observed that agriculture is negatively correlated withall other variables except recreation, whereas fish catch is positively correlated with all other variables except agriculture and recreation (Table 1). There is strong convergence of opinion between the social security and fish catch (Table 1).

Table 1: Correlation Matrix

		A	F	R	S	T	B	H	E
Correlation	A	1.000	-.304	.334	-.122	-.132	-.259	-.024	-.029
	F	-.304	1.000	-.029	.718	.031	.196	.124	.189
	R	.334	-.029	1.000	.298	-.038	.205	-.049	-.043
	S	-.122	.718	.298	1.000	-.092	.362	-.041	.056
	T	-.132	.031	-.038	-.092	1.000	-.247	.090	-.314
	B	-.259	.196	.205	.362	-.247	1.000	-.087	.217
	H	-.024	.124	-.049	-.041	.090	-.087	1.000	.302
	E	-.029	.189	-.043	.056	-.314	.217	.302	1.000

Table 2: Total Variance Explained

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	2.140	26.753	26.753	2.140	26.753	26.753	2.065	25.807	25.807
2	1.483	18.540	45.293	1.483	18.540	45.293	1.481	18.509	44.316
3	1.364	17.056	62.349	1.364	17.056	62.349	1.443	18.033	62.349
4	1.138	14.226	76.575						
5	.796	9.949	86.524						
6	.509	6.358	92.882						
7	.390	4.876	97.758						
8	.179	2.242	100.000						

Extraction Method: Principal Component Analysis.

Table 3.a. Component Matrix

	Component		
	1	2	3
A	-.374	.680	.111
F	.798	-.291	-.184
R	.193	.739	-.235
S	.832	.138	-.341
T	-.248	-.463	-.532
B	.642	.227	.057
H	.091	-.325	.502
E	.389	-.005	.780

Table 3.b. Rotated Component Matrix (Varimax with Kaiser Normalization)

	Component		
	1	2	3
A	-.402	.665	.105
F	.820	-.265	.025
R	.243	.760	-.032
S	.894	.163	-.036
T	-.001	-.356	-.654
B	.588	.190	.291
H	-.065	-.409	.441
E	.127	-.152	.849

The Eigen value for the first component is 2.14 i.e. 27% variance is explained (Table 2). The cumulative Eigen value for the first three components is more 62% i.e. the nature of relationship between the socio-economic variable is moderate and not so strong. It shows divergence of opinion of the people in different variables.

From the component matrix it is clear that Fish Catch (F), Issue of Social Security (S) and Building Quality (B) positively control the system in the first component. Agriculture (A), Recreation (R) controls the system in positive direction for the 2nd component. Transport (T) runs the system in negative direction for the 3rd component whereas Education (E) and Health (H) control the system in the positive direction for the 3rd component (Table 3a.). After rotation there is a slight change in the component matrix (Table 3.b).

Finally from the component plot it has been observed that there is symmetry in the opinion of the people regarding education and health access. Clustering has been observed between building quality and social security (Fig. 7). For other variable association is weak signifying divergence of opinion for the concerned variables.

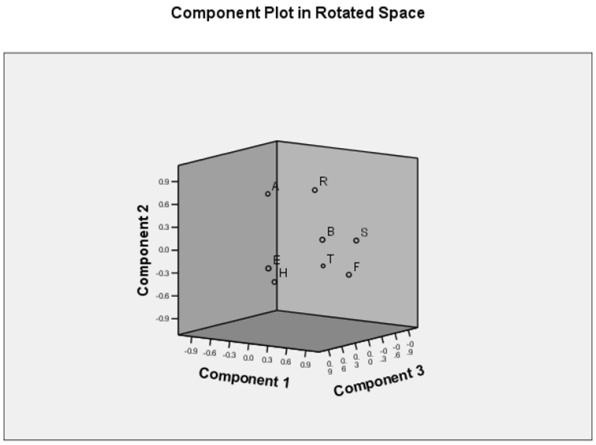

Fig. 7. Component plot of the socio-economic variables after varimax rotation

5. CONCLUSION

From the research work it has been found that channel cutoff is not only a mere geomorphic phenomenon, but it also has a great socio-economic impact.The socio-economic mosaics of ChakundiVillage have been greatly influenced by channel cutoff. It has been seen that the nature and intensity of the flood and bank erosion has been decreased pronouncedly after the cutoff. The overall productivity and consistency of agricultural production has been increased. The potentiality of fishing has been increased after cutoff. Channel cutoff has positive impact on social security, as it has left the palaeo channels as a natural barrier. But channel cutoff has negative impacts on recreational environment, transport system, health care services and accessibility to education.

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